7. The practical value of laboratory evidence as to the presence of disease of the heart muscle is inversely proportionate to the skill of the attending physician in interpreting clinical evidence as to the imminence or presence of heart failure. Such skill is possessed chiefly by the internist. Yet internists furnished 61.5 per cent. of all cases examined. The statistics of other heart stations would probably be similar. It becomes, therefore, the duty of the internist to instruct members of other branches of the profession regarding the necessity of more frequent use of instruments of precision in the diagnosis and prognosis of disease of heart muscle.

NOTE.—The authors acknowledge their indebtedness to Dr. A. P. D'zmura for assistance in the preparation of this paper.

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# OBSERVATIONS ON NEGATIVITY OF THE FINAL VENTRICULAR T WAVE OF THE ELECTROCARDIOGRAM.*

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A REVIEW of the literature on electrocardiography, both experimental and clinical, at once reveals a variance in views as to the interpretation of the normal electrocardiogram. The two views that have gained broadest recognition are: (1) All waves are manifestations of excitation and contraction of heart muscle, and (2) the waves result from electric changes accompanying conduction of the impulse and contraction of the muscle.

Einthoven assumed that the right ventricle represents the cardiac base and the left ventricle the apex, and that the dominance of negativity in the right ventricle causes an upward deflection while dominance in the left causes a downward deflection of the galvanometer. Thus the *R* wave is ascribed to contraction of the right heart, the *S* wave to contraction of the left heart and the horizontal *S-T* interval to neutralization of basal and apical negativity. The *T* wave represents contraction of the right ventricular base outlasting that of the left.

Eppinger and Rothberger object to Einthoven's assumption in ascribing the rôle of cardiac base to the relatively weak right ventricle and regarding the left ventricle with its massive muscle bulk as the apex.

The views of Kraus and Nicolai are based on the structural arrangement of the ventricular musculature into systems. Following auricular contraction the impulse passes through the auriculoventricular bundle and its contiguous structures. The long *P–R* interval is explained by slow conduction and the absence of appreciable action currents at this time due to the small muscle mass. The *R* wave is ascribed to primary activity of the basal portions of the papillary muscles. As the excitation wave spreads toward the apex the termination of the *R* wave occurs. The *S–T* interval is explained by the absence of potential between base and apex. The *T* wave results from late return of negativity to the base.

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The views of Einthoven, Kraus and Nicolai agree in general in emphasizing the antagonistic action of electric potential between base and apex.

In distinct opposition to the views already expressed, Hoffmann concluded that the electrocardiogram results from two actions, impulse conduction and muscle contraction. The *Q R S* complex results from passage of the impulse through the ventricular conduction system and the *S–T* interval and the *T* wave from electric potential caused by the contracting ventricle. Hoffmann produced standstill of the frog heart by the application of muscarin, obtained simultaneous electrocardiographic and ventricular suspension curves and found that the electrocardiogram of the nonbeating heart differs from the normal only in the absence of the *T* wave. When the muscarin effect was abolished by atropin and the beats returned the *T* wave reappeared.

Eyster and Meek, as a result of their experimental work on the relation of the line of isopotential to the formation of the electrocardiogram and their critical review of the literature, in general agree with Hoffmann's theory. They believe the *R* wave to be concerned with conduction, but they do not ascribe definite structures as conducting mediums. The *T* wave is the expression of preponderance of contraction on one side of the line of equipotential. Eyster and Meek further show the differences between physiologic curves of conduction and contraction. When a nerve is stimulated where conduction alone occurs a single monophasic or diphasic electric response occurs. In skeletal muscle this rapid electric change is followed by a slower and more prolonged electric variation. This conforms with the general contour of the electrocardiographic deflections; the *R* wave is abrupt and steep, the *T* wave blunt and prolonged.

## CARDIAC EVENTS AND THE ELECTROCARDIOGRAM.

The relationship of the waves of the electrocardiogram to definitely known cardiac events strongly supports the "conduction contraction" theory. By a consideration of accepted relationships of the normal heart sounds a working basis for comparison is established.

Einthoven, Flohil and Battaerd have shown that the first sound begins at the initiation of ventricular systole and lasts from 0.07 to 0.10 second, is followed by a pause varying from 0.15 to 0.25 second and then succeeded by the second sound. These observations have been confirmed by other investigators.[1 10 35] The second sound follows closely on the closure of the semilunar valves,[37] begins simultaneously with the rise of intraventricular pressure[11] and gains its maximum amplitude during this period.[33] That the second sound is an early diastolic event has been shown clearly.[26 36]

Kahn has demonstrated that the first sound falls in the pause between the *R* and the *T* waves and begins at the moment the *R* wave disappears and a short time before the rise of the *T* wave. The second sound begins 0.05 second after the end of the *T* wave. This relationship reveals the fact that the *R* wave is completed before ventricular contraction begins and indicates conduction rather than contraction. The *T* wave definitely occupies the period associated with actual ventricular contraction.

In clinical studies of the abnormalities of the *Q R S* group they are largely ascribed to disease of the ventricular conduction system.[3 24 34 38 31] It must be recognized, however, that the graphic representation of contraction in the electrocardiogram is the expression of changes in electric potential and not the translation of actual contraction. The iso-electric portion of the intervals *S–T* and a portion of *T–P* are not latent in the sense of a refractory phase.

## CONSIDERATION OF ELECTROPOTENTIAL.

Waller and Reid demonstrated a line of equipotential passing through the heart from base to apex in relation to any two derivations from the extremities. A preponderance of negativity above this line, representing the cardiac base, caused deflection of the galvanometer connected to both upper extremities in a manner to indicate relative negativity of the electrode connected with the right arm. The arm becomes relatively negative in derivations from an arm and a leg. Dominance of negativity below the equipotential line deflects the galvanometer in the opposite direction.

## HYPOTHESIS OF *T*-WAVE NEGATIVITY.

The three derivations of the electrocardiogram possess symbols of definite electropotential in relation to their electrodes. In the normal electrocardiogram derivation 1 bears symbols as follows: right arm –, left arm +; derivation 2, right arm –, left leg +; and derivation 3, left arm –, left leg + (Fig. 1). This arragement implies positive or upright deflections in all derivations of the electrocardiogram. If it is assumed that the "conduction-contraction" theory is correct the *T* wave is the expression of preponderance of contraction on one side of the line of equipotential. *T*-wave negativity (inverted) therefore results from changes in contraction preponderance. The negativity of this wave in certain isolated or combined derivations of the electrocardiogram is indicative of definite potential changes affecting contraction preponderance in various regions of the cardiac musculature.

In the normal heart, therefore, according to standard derivations, the *T* wave in all derivations is positive (upright), the upper right zone of potential is strongly electronegative to the apical zone while the left upper zone is iso-electric. This potential arrangement is illustrated in Fig. 1.

For reasons of simplification I have represented the three derivations by the sides of an equilateral triangle. To prevent misunderstanding it should be stated that the schematic figure employed, divided into zones of electropotential, is not based on mathematic consideration. The right upper zone in general corresponds to the sinus region of the heart and in the normal potential arrangement is electronegative.

Confirmation of this is found in the researches of Keith and Flack, Wybauw, Lewis, Oppenheimer and Oppenheimer, Brandenburg and Hoffmann, and Ganter and Zahn, who have shown that the cardiac impulse takes its origin in a collection of specialized tissue, a remnant of the primordial sinus. This structure lies in the sulcus terminalis at the juncture of the superior vena cava and the right auricular appendage, and is the seat of primary cardiac negativity.

Changes in the normal potential distribution produce *T* wave negativity in isolated or combined derivations of the electrocardiogram. Reversal of potential in one derivation alters cardiac potential so that *T*-wave negativity in that derivation occurs.

## *T*-WAVE NEGATIVITY.

Many opinions have been expressed as to the significance of negativity or inversion of the *T* wave in isolated or combined derivations of the electrocardiogram.

The effect of digitalis on the heart as manifested by negativity of the *T* wave is well known;[4] it has been ascribed to muscular ventricular redistribution or possibly to alteration in muscular contractility. These changes are not permanent.

Numerous statements may be found in which myocardial damage is ascribed to *T*-wave negativity in certain derivations,[3 18 19 25] and again these occurrences have been noted in apparently normal hearts[13 20 31] affecting largely derivation 3.

Smith during his experimental work on coronary ligations observed interesting changes in the *T* wave. The most constant

Positive T wave in all Derivations (normal)

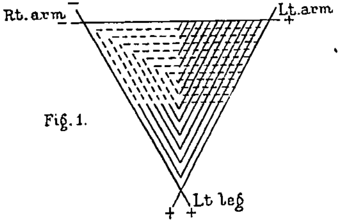

Fig. 1.

Negative T wave in Derivation I.

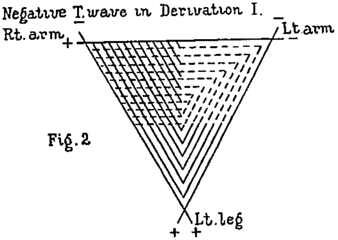

Fig. 2

Negative T wave in Derivation III.

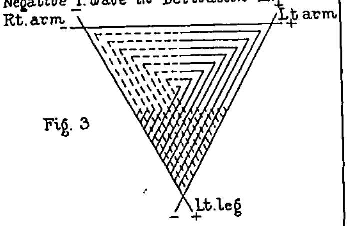

Fig. 3

Negative T wave in Derivations I and II.

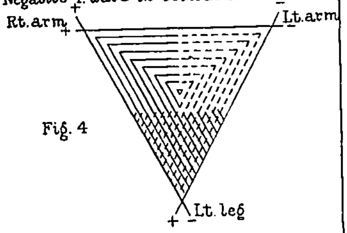

Fig. 4

Negative T wave in Derivations II and III

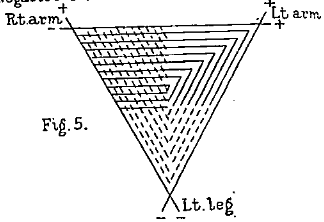

Fig. 5.

Negative T wave in Derivations I, II and

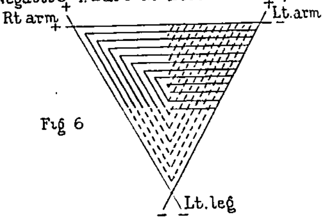

Fig 6

Diffuse iso-electric state of heart if nega
T. wave in Derivation II occurred.

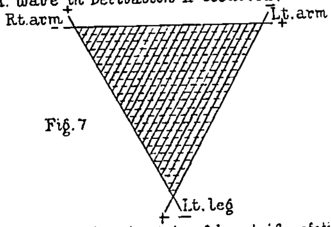

Fig. 7

Diffuse iso-electric state of heart if negati
T. wave in Derivations I and III occurre

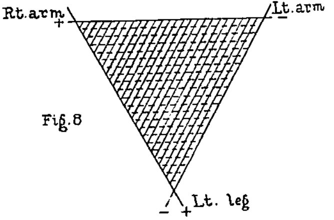

Fig. 8

Observations on negativity of the final ventricular *T* wave of the electrocardiogram.

changes in the electrocardiogram following ligation of any branch of the left coronary artery affected the *T* wave. A strongly positive to a markedly negative wave resulted fairly constantly with a slower return to positive or iso-electric. The negativity was usually observed within twenty-four hours after ligation and lasted for from three to four days. The duration seemed to bear a relationship to the size of the artery ligated. This work offers a tangible basis in directing attention to changes in the intrinsic blood supply of the heart, as evidenced by greater or lesser derangements of cardiac function. Morison has shown that blood-volume alterations may produce changes detectable in the electrocardiogram.

Increased general cellular function implies increased blood volume for the maintenance of normal tissue metabolism. In a specialized organ this augmentation is manifested by an increase in its function. In the heart increase in the blood volume beyond physiologic limits increases contraction. I refer particularly to increase of ventricular blood volume, since coronary volume is largely dependent on this factor. Because of impairment or disease of certain intrinsic channels of blood supply the affected muscle does not receive the requisite amount of blood properly to maintain function while the unaffected muscle demands greater blood volume for relatively more efficient contraction. This is an explanation for *T*-wave changes in isolated or combined derivations occurring permanently or temporarily.

## THE ACTION OF THE CARDIAC NERVES ON *T*-WAVE NEGATIVITY.

Stimulation of the cardiac vagus has been shown to produce negativity of the *T* wave,[5, 29] and the same observation is noted following stimulation of the left cervical sympathetic branches.[28]

A series of clinical observations were conducted on patients having negative *T* waves in isolated or combined derivations of their electrocardiograms. Following the initial tracing, pressure was applied in turn to the right vagus region in the neck, to the left vagus region and finally to the right eyeball (oculocardiac reflex) and the respective electrocardiograms obtained. In no instance was any change noted in the negative *T* wave or in the positive *T* wave of the unaffected derivations. Atropin (gr. $\frac{1}{150}$) was then administered subcutaneously and records obtained every ten minutes for forty minutes. Again no effect on the *T* wave was noted. No change occurred following the subcutaneous administration of adrenalin (0.5 c.c. of a 1 to 1000 solution). These clinical procedures, however, are obviously not so accurate as direct experimental stimulation.

The present status of cardiac histopathology fails to explain many derangements of function. Histologic studies do not indicate why auricular fibrillation occurs in one heart and auricular flutter in another. Disease of the cardiac conduction system is more definite histologically. Involvement below the auriculo-ventricular bundle is often associated with unquestionable intrinsic vascular changes.

There has been no adequate explanation of the occurrence of the negative *T* wave in isolated or combined derivations of the electrocardiogram. In the Mayo Clinic we have repeatedly observed the negative *T* wave in derivation 1, in derivation 3, in combined derivations 1 and 2, in combined derivations 2 and 3 and in combined derivations 1, 2 and 3. No instances of negativity in derivation 2 or in combined derivations 1 and 3 are recorded. This observation in 7000 electrocardiographic examinations eliminates the element of coincidence. There is a definite reason why these changes do not occur. Lewis states that the *T* wave is always upright in derivation 2 alone.

*T-wave Negativity in Derivation 1* (Fig. 2). Fig. 2 represents the arrangement of potential existing with this abnormality. The left arm becomes electronegative to the right while the other signs remain unchanged. The right upper zone instead of being electronegative becomes iso-electric while the left upper becomes electronegative to the apex. The occurrence of an iso-electric state in the right upper zone is a marked departure from the normal in that the area of primary electronegativity is altered.

*T-wave Negativity in Derivation 3* (Fig. 3). The left leg becomes electronegative to the left arm; the other derivations remain unchanged. The right upper zone remains electronegative with reference to the left upper. The apical zone becomes iso-electric. This distribution is but a slight deviation from normal in that the right upper zone remains electronegative.

*T-wave Negativity in Combined Derivations 1 and 2* (Fig. 4). The left arm becomes electronegative to the right arm and the left leg electronegative to the right arm. The third derivation remains unchanged. The left upper zone becomes electronegative to the right and the apical zone becomes iso-electric. This arrangement again deviates from the normal in altering the area of primary electronegativity; it is a lesser change in that the right upper zone becomes electropositive instead of iso-electric.

*T-wave Negativity in Combined Derivations 2 and 3* (Fig. 5). The left leg becomes electronegative to both arms. Derivation 1 remains unchanged. The apical zone becomes electronegative to the left upper while the right upper zone becomes iso-electric. This arrangement as in Derivation 1 is a marked change from normal in that the area of primary electronegativity becomes iso-electric.

*T-wave Negativity in Combined Derivations 1, 2 and 3* (Fig. 6). All derivations reverse their signs in relation to each other. The apical zone becomes electronegative to the right upper while the left upper zone becomes iso-electric. The upper zones assume just the opposite relationship to each other that occurs in combined derivations 2 and 3. Here again the potential distribution is disturbed, the area of primary electronegativity becoming electropositive, approaching the changes accompanying *T*-wave negativity in combined derivations 1 and 2.

Figs. 7 and 8 illustrate the reason why *T*-wave negativity in derivation 2 and in combined derivations 1 and 3 does not occur. In derivation 2 the left leg would be electronegative to the right arm while the other derivations would remain unchanged. This distribution would imply a diffuse iso-electric cardiac state and would indicate that cardiac contraction had ceased. In combined derivations 1 and 3 the left arm would be electronegative to the right and the left leg to the left arm. This arrangement likewise would indicate a diffuse iso-electric state.

The greater the deviation from the normal potential distribution the greater the significance of the disorder responsible for the change. The greatest change occurring which is compatible with life is the iso-electric state occupying the right upper zone. Therefore *T*-wave negativity in derivation 1 and in combined derivations 2 and 3 should be associated generally with grave heart disease. Next in significance should be those distributions of potential rendering the left upper zone electronegative to the right and represented by *T*-wave negativity in combined derivations 1 and 2 and in combined derivations 1, 2 and 3.

In the distribution which most closely approximates normal the *T* wave is negative in derivation 3. In these cases the normal potential relationship of the right upper zone is maintained.

## CLINICAL CONSIDERATION OF *T*-WAVE NEGATIVITY.

This study comprises 1106 cases of *T*-wave negativity in the electrocardiograms. One hundred and forty instances (12.6 per cent.) were noted in derivation 1, 688 (62.2 per cent.) in derivation 3, 62 (5.6 per cent.) in combined derivations 1 and 2, 171 (15.5 per cent.) in combined derivations 2 and 3, and 45 (4.1 per cent.) in combined derivations 1, 2 and 3. There was no instance of *T*-wave negativity in derivation 2 nor in combined derivations 1 and 3. Patients who had had digitalis within six weeks of the time of electrocardiographic examination were not included in this series.

## *T*-WAVE NEGATIVITY AND VENTRICULAR PREPONDERANCE.

In the complete series about half (46.6 per cent.) of the electrocardiograms were associated with preponderance of the left ventricle. Preponderance of the right ventricle is evidenced by a negative *R* wave in derivation 1 and by a positive *R* wave in derivation 3. In cases of preponderance of the left ventricle these changes are reversed. Right preponderance was infrequent (17.3 per cent.) and no unbalance was present in 36.1 per cent. of the electrocardiograms. Preponderance of the left ventricle occurred most often associated with *T*-wave negativity in derivation 1 and in combined derivations 1 and 2. No instance of right preponderance was noted with negativity in combined derivations 1, 2 and 3. These observations are summarized in Table I.

TABLE I.—T-WAVE NEGATIVITY AND VENTRICULAR PREPONDERANCE.

| Derivation. | Total. | Left preponderance. | Percentage. | Right preponderance. | Percentage. | None. | Percentage. |
|---|---|---|---|---|---|---|---|
| 1 . . . . . . . . . . | 140 | 120 | 85.7 | 5 | 3.6 | 15 | 10.7 |
| 3 . . . . . . . . . . | 688 | 274 | 39.8 | 132 | 19.2 | 282 | 41.0 |
| 1 and 2 . . . . . . . . | 62 | 52 | 83.9 | 4 | 6.4 | 6 | 9.7 |
| 2 and 3 . . . . . . . . | 171 | 43 | 25.2 | 51 | 29.8 | 77 | 45.0 |
| 1, 2 and 3 . . . . . . . | 45 | 27 | 60.0 | 0 | 0 | 18 | 40.0 |
| Total . . . . . . . . | 1106 | 516 | 46.6 | 192 | 17.3 | 398 | 36.1 |

TABLE II.—GRAVE HEART DISEASE ASSOCIATED WITH T-WAVE NEGATIVITY.

| Derivation. | Total. | Arborization block. | Delayed auriculoventricular conduction. | Complete auriculoventricular dissociation. | Auricular fibrillation. | Auricular flutter. | Ventricular tachycardia. | Aortic disease. | Angina pectoris. |
|---|---|---|---|---|---|---|---|---|---|
| 1 . . . . . . | 140 | 53 | 3 | 3 | 19 | 1 | 1 | 16 | 9 |
| 3 . . . . . . | 688 | 3 | 2 | 0 | 11 | 0 | 0 | 8 | 21 |
| 1 and 2 . . . . | 62 | 14 | 2 | 0 | 5 | 0 | 1 | 6 | 1 |
| 2 and 3 . . . . | 171 | 11 | 3 | 1 | 24 | 0 | 1 | 13 | 3 |
| 1, 2 and 3 . . . | 45 | 3 | 3 | 0 | 11 | 0 | 0 | 8 | 2 |
| Total . . . | 1106 | 84 | 13 | 4 | 70 | 1 | 3 | 51 | 36 |

## ASSOCIATED DISEASES.

*T-wave Negativity in Derivation 1 (140 cases).* Myocardial degeneration associated with the hypertension group occurred with greatest frequency (38.6 per cent.) in the patients having *T*-wave negativity in derivation 1 of their electrocardiograms. Three factors are probably responsible for the myocardial changes accompanying hypertension: (1) The cause or causes primarily responsible for the constitutional disorder; (2) the action on the myocardium of the retention products or of the intermediate products of incomplete metabolism or toxic agents resulting from imperfect renal or tissue function; and (3) the increased cardiac work, affecting largely the myocardium, resulting from the hypertension *per se* and the alterations in cardiovascular balance.

Chronic endocarditis occurred second in order of frequency (22.1 per cent. of the cases). The myocardial damage attending this disorder occurs concomitant with or secondary to the endocardial invasion (Table III). In no instance was the cardiac examination negative. In the majority of instances grave heart disease was present.

TABLE III.—ASSOCIATED DISEASES. T-WAVE NEGATIVITY IN DERIVATION 1.

| Decade. | Total. | Degenerative processes. | | | Infections. | | | Local nutritional disturbances. | | Congenital heart disease. | No cardiac findings. | Inconclusive cardiac findings. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hypertension with and without clinical nephritis. | Exophthalmic goiter. | Adenomas with hyperthyroidism. | Chronic endocarditis. | Chronic myocarditis. | Syphilis. | Arteriosclerosis. | Angina pectoris. | | | |
| 11 to 20 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 to 30 | 5 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 to 40 | 7 | 1 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 1 |
| 41 to 50 | 28 | 10 | 2 | 2 | 7 | 1 | 5 | 1 | 1 | 0 | 0 | 0 |
| 51 to 60 | 40 | 16 | 1 | 2 | 6 | 6 | 2 | 7 | 4 | 0 | 0 | 0 |
| 61 to 70 | 54 | 25 | 0 | 2 | 9 | 7 | 0 | 11 | 4 | 0 | 0 | 0 |
| 71 to 80 | 4 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 140 | 54 | 3 | 6 | 31 | 19 | 7 | 19 | 9 | 0 | 0 | 1 |
| Per cent | ... | 45 | | | 40.7 | | | 13.6 | | ... | ... | 0.7 |

Fifty-three patients had arborization block, 3 had delayed auriculoventricular conduction, 3 had complete auriculoventricular dissociation, 19 had auricular fibrillation, 1 had auricular flutter and 1 had ventricular tachycardia. Sixteen patients had aortic disease. Nine had angina pectoris.

The high incidence of grave heart disease in this group verifies my previous statement regarding the potential distribution responsible for this negativity as being the greatest departure from normal. The right upper zone is iso-electric instead of electronegative.

*T-wave Negativity in Derivation 3 (688 Cases).* The relative frequency of *T*-wave negativity occurring in derivation 3 is at once apparent.

The myocardial degeneration secondary to exophthalmic goiter was the most frequently associated condition (19.2 per cent.). Myocardial damage due to exophthalmic goiter involves the cellular action of thyroxin[17] (thyroid active principle) on the myocardium[27] and the increased cardiac work accompanying the rise of the basal metabolic rate.

Chronic endocarditis occurred in 16.9 per cent. and chronic myocarditis in 14.8 per cent. By chronic myocarditis I refer to those cases of inflammatory origin in contradistinction to the cases of myocardial degeneration. Myocardial degeneration associated with the hypertension group occurred in only 10.8 per cent. of cases (Table IV).

TABLE IV.—ASSOCIATED DISEASES. T-WAVE NEGATIVITY IN DERIVATION 3.

| Decade. | Total. | Degenerative processes. | | | Infections. | | | Local nutritional disturbances. | | Congenital heart disease. | No cardiac findings. | Inconclusive cardiac findings. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hypertension with and without clinical nephritis. | Exophthalmic goiter. | Adenomas with hyperthyroidism. | Chronic endocarditis. | Chronic myocarditis. | Syphilis. | Arteriosclerosis. | Angina pectoris. | | | |
| 1 to 10 | 10 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 2 |
| 11 to 20 | 62 | 2 | 20 | 0 | 13 | 2 | 1 | 0 | 0 | 0 | 22 | 2 |
| 21 to 30 | 190 | 6 | 55 | 3 | 40 | 19 | 2 | 0 | 0 | 1 | 46 | 18 |
| 31 to 40 | 161 | 12 | 39 | 5 | 32 | 15 | 6 | 0 | 0 | 0 | 35 | 17 |
| 41 to 50 | 138 | 28 | 16 | 5 | 18 | 25 | 5 | 4 | 4 | 1 | 19 | 17 |
| 51 to 60 | 83 | 21 | 2 | 9 | 5 | 27 | 5 | 7 | 6 | 0 | 1 | 6 |
| 61 to 70 | 39 | 4 | 0 | 2 | 4 | 12 | 0 | 12 | 10 | 0 | 2 | 3 |
| 71 to 80 | 5 | 1 | 0 | 0 | 0 | 2 | 0 | 2 | 1 | 0 | 0 | 0 |
| Total | 688 | 74 | 132 | 24 | 116 | 102 | 19 | 25 | 21 | 6 | 125 | 65 |
| Per cent. | ... | 33.4 | | | 34.4 | | | 3.7 | | 0.9 | 18.2 | 9.4 |

Grave heart disease is relatively infrequent in this group; 3 patients had arborization block, 2 had delayed auriculoventricular conduction and 11 auricular fibrillation. Eight patients had aortic disease and 21 had angina pectoris. Twenty per cent. of the patients had no demonstrable evidence of organic heart disease. Of this number 40 per cent. had cardiac neurosis.

The relative infrequency of grave heart disease and the high percentage of apparently normal hearts in this group are in marked contrast to the findings associated with *T*-wave negativity in derivation 1. These findings are in accord with the hypothetic significance of *T*-wave negativity in derivation 3. The potential distribution in this *T*-wave negativity is illustrated in Fig. 3. The right upper zone remains electronegative, the other zones reverse their potential, establishing an arrangement which does not materially depart from the normal.

The potential distribution occurring in such a relatively high percentage of apparently normal hearts and the frequent transient *T*-wave negativity in derivation 3 make functional myocardial fatigue a causative possibility in a certain number of cases at least.

*T-wave Negativity in Combined Derivations 1 and 2 (62 Cases).* Myocardial degeneration associated with the hypertension group occurred in half (50 per cent.) of the patients having *T*-wave negativity in combined derivations 1 and 2. Chronic endocarditis was present in 20.9 per cent. of the cases. In no instance was the cardiac examination negative. These findings are summarized in Table V. About half (46.7 per cent.) of the cases were associated with grave heart disease. Fourteen patients had arborization block, 2 had delayed auriculoventricular conduction, 5 had auricular fibrillation and 1 had ventricular tachycardia. Six patients had aortic disease and 1 of these had an aortic aneurysm. One patient had angina pectoris.

TABLE V.—ASSOCIATED DISEASES. T-WAVE NEGATIVITY IN DERIVATIONS 1 AND 2.

| Decade. | Total. | Degenerative processes. | | | Infections. | | | Local nutritional disturbances. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hypertension with and without clinical nephritis. | Exophthalmic goiter. | Adenomas with hyperthyroidism. | Chronic endocarditis. | Chronic myocarditis. | Syphilis. | Arteriosclerosis. | Angina pectoris. | Congenital heart disease. | No cardiac findings. | Inconclusive cardiac findings. |
| 21 to 30 | 7 | 0 | 0 | 0 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 to 40 | 5 | 3 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41 to 50 | 13 | 7 | 0 | 1 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 1 |
| 51 to 60 | 20 | 14 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 61 to 70 | 15 | 7 | 0 | 1 | 2 | 1 | 1 | 3 | 0 | 0 | 0 | 0 |
| 71 to 80 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| Total | 62 | 31 | 1 | 2 | 13 | 7 | 2 | 5 | 1 | 0 | 0 | 1 |
| Per cent. | ... | 54.8 | | | 35.5 | | | 8.1 | | ... | ... | 1.6 |

Reference to the potential distribution responsible for *T*-wave negativity in this derivation combination (Fig. 4) shows that the normal potential (electronegativity) of the right upper zone is disturbed. The left upper zone becomes electronegative to the right upper. Although this is a distinct departure from normal it is less marked than those states in which the right upper zone becomes iso-electric.

*T-wave Negativity in Combined Derivations 2 and 3 (171 Cases).* Chronic endocarditis occurred with greatest frequency (26.9 per cent.) in those patients having *T*-wave negativity in combined derivations 2 and 3. In order of frequency followed myocardial degeneration associated with exophthalmic goiter (21 per cent.), chronic myocarditis (17.5 per cent.), and myocardial degeneration associated with the hypertension group (15.8 per cent.).

A large percentage of the patients had grave heart disease. Eleven patients had arborization block, 3 had delayed auriculoventricular conduction, 1 had complete auriculoventricular dissociation, 24 had auricular fibrillation and 1 ventricular tachycardia. Thirteen patients had aortic disease and 3 had angina pectoris. In 9 cases the cardiac examination was negative. These observations are illustrated in Table VI.

TABLE VI.—ASSOCIATED DISEASES. T-WAVE NEGATIVITY IN DERIVATIONS 2 AND 3.

| Decade. | Total. | Degenerative processes. | | | Infections. | | | Local nutritional disturbances. | | Congenital heart disease. | No cardiac findings. | Inconclusive cardiac findings. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hypertension with and without clinical nephritis. | Exophthalmic goiter. | Adenomas with hyperthyroidism. | Chronic endocarditis. | Chronic myocarditis. | Syphilis. | Arteriosclerosis. | Angina pectoris. | | | |
| 11 to 20 | 12 | 1 | 4 | 0 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 to 30 | 45 | 1 | 13 | 0 | 16 | 6 | 1 | 0 | 0 | 0 | 5 | 2 |
| 31 to 40 | 39 | 4 | 10 | 1 | 14 | 4 | 0 | 0 | 0 | 1 | 3 | 3 |
| 41 to 50 | 34 | 5 | 8 | 3 | 6 | 8 | 1 | 0 | 0 | 2 | 1 | 0 |
| 51 to 60 | 28 | 10 | 0 | 1 | 4 | 8 | 0 | 4 | 2 | 0 | 0 | 1 |
| 61 to 70 | 12 | 5 | 1 | 0 | 1 | 2 | 1 | 2 | 1 | 0 | 0 | 0 |
| 71 to 80 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 171 | 27 | 36 | 5 | 46 | 30 | 3 | 6 | 3 | 3 | 9 | 6 |
| Per cent. | ... | 39.8 | | | 46.2 | | | 3.5 | | 1.7 | 5.3 | 3.5 |

Again the reader is referred to Fig. 5, which illustrates the potential distribution in *T*-wave negativity in this derivation combination. The similarity to the potential arrangement attending *T*-wave negativity in derivation 1 may be noted.

*T-wave Negativity in Combined Derivations 1, 2 and 3 (45 Cases).* *T*-wave negativity in derivations 1, 2 and 3 constituted the smallest group, comprising only 4.1 per cent. of the total series.

Myocardial degeneration associated with the hypertension group occurred most often (35.5 per cent.), and in order of occurrence chronic endocarditis (24.4 per cent.) and chronic myocarditis (20 per cent.). Every patient in this group had definite clinical evidence of heart disease (Table VII).

TABLE VII.—ASSOCIATED DISEASES. T-WAVE NEGATIVITY IN DERIVATIONS 1, 2 AND 3.

| Decade. | Total. | Degenerative processes. | | | Infections. | | | Local nutritional disturbances. | | Congenital heart disease. | No cardiac findings. | Inconclusive cardiac findings. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hypertension with and without clinical nephritis. | Exophthalmic goiter. | Adenomas with hyperthyroidism. | Chronic endocarditis. | Chronic myocarditis. | Syphilis. | Arteriosclerosis. | Angina pectoris. | | | |
| 11 to 20 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 to 30 | 4 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 31 to 40 | 7 | 1 | 0 | 0 | 4 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 41 to 50 | 9 | 2 | 1 | 2 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 |
| 51 to 60 | 12 | 8 | 0 | 0 | 2 | 0 | 0 | 2 | 1 | 0 | 0 | 0 |
| 61 to 70 | 12 | 5 | 0 | 0 | 2 | 4 | 0 | 1 | 1 | 0 | 0 | 0 |
| Total | 45 | 16 | 1 | 2 | 11 | 9 | 2 | 3 | 2 | 1 | 0 | 0 |
| Per cent. | ... | 42.2 | | | 48.8 | | | 6.6 | | 2.2 | | |

Three of the patients with the graver forms of heart disease had arborization block, 3 delayed auriculoventricular conduction and 11 auricular fibrillation. Eight patients had aortic disease and 2 had angina pectoris. If the potential distribution in this disorder is taken into consideration the apical zone will be found electronegative to the right upper while the left upper zone will be iso-electric (Fig. 6). This arrangement is similar to that attending *T*-wave negativity in combined derivations 1 and 2 in that the right upper zone is electropositive. It likewise is a distinct deviation from normal.

## TABLE VIII.—ELECTROCARDIOGRAPHIC CHANGES ASSOCIATED WITH T-WAVE NEGATIVITY.

| Derivation. | Total. | T-wave negativity unattended. | Sinus arrhythmia. | Auricular premature contractions. | Auricular and nodal premature contractions. | Auricular and ventricular premature contractions. | Nodal premature contractions. | Nodal premature contractions and sinus arrhythmia. | Ventricular premature contractions. | Ventricular and nodal premature contractions. | Ventricular premature contractions and sinus arrhythmia. | Auricular fibrillation. | Auricular fibrillation and ventricular premature contractions. | Auricular fibrillation and aberrant Q R S complexes in isolated derivations. | Auricular fibrillation and aberrant Q R S complexes in isolated derivations and ventricular premature contractions. | Arborization block. | Arborization block and auricular premature contractions. | Arborization block and ventricular premature contractions. | Arborization block and auricular fibrillation. | Arborization block and delayed auriculoventricular conduction. | Aberrant Q R S complexes in isolated derivations. | Aberrant Q R S complexes in isolated derivations and auricular premature contractions. | Aberrant Q R S complexes in isolated derivations and ventricular premature contractions. | Delayed auriculoventricular conduction. | Delayed auriculoventricular conduction and sinus arrhythmia. | Delayed auriculoventricular conduction, aberrant Q R S complexes in isolated derivations and ventricular premature contractions. | Complete auriculoventricular dissociation. | Auricular flutter. | Nodal tachycardia. | Ventricular tachycardia. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 . . . . | 140 | 41 | 0 | 2 | 0 | 6 | 0 | 0 | 11 | 0 | 0 | 8 | 6 | 1 | 0 | 36 | 3 | 8 | 4 | 2 | 2 | 1 | 2 | 1 | 0 | 0 | 3 | 1 | 1 | 1 |
| 3 . . . . | 688 | 550 | 24 | 14 | 1 | 8 | 4 | 1 | 40 | 0 | 1 | 17 | 4 | 0 | 1 | 10 | 0 | 2 | 0 | 0 | 10 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 and 2 . . | 62 | 32 | 0 | 2 | 0 | 2 | 1 | 0 | 2 | 1 | 0 | 3 | 1 | 0 | 0 | 11 | 0 | 1 | 1 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 2 and 3 . . | 171 | 112 | 1 | 5 | 0 | 1 | 1 | 0 | 10 | 1 | 0 | 20 | 4 | 0 | 0 | 4 | 0 | 5 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| 1, 2 and 3 . | 45 | 21 | 0 | 2 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 8 | 3 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 |
| Total . | 1106 | 756 | 25 | 25 | 1 | 17 | 6 | 1 | 67 | 2 | 1 | 56 | 18 | 1 | 1 | 63 | 3 | 17 | 6 | 4 | 16 | 1 | 3 | 5 | 1 | 1 | 4 | 1 | 1 | 3 |

TABLE IX.—VALVULAR DISEASE ASSOCIATED WITH T-WAVE NEGATIVITY.

| Decade. | Total. | Mitral disease. | | | | | | Aortic disease. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mitral regurgitation. | Mitral stenosis. | Double mitral lesion. | Mitral and polyvalvular regurgitation. | Double mitral lesion and aortic regurgitation. | Mitral stenosis and aortic regurgitation. | Aortic regurgitation. | Aortic stenosis. | Double aortic lesion. | Aortitis. | Aortic regurgitation and aortitis. | Aortic and polyvalvular regurgitation. | Aortic and mitral regurgitation. |
| 1 . . . . . | 37 | 16 | 0 | 2 | 1 | 2 | 0 | 3 | 2 | 2[1] | 2[2] | 5[3] | 2[1] | 0 |
| 3 . . . . . | 122 | 64 | 27 | 7 | 0 | 2 | 0 | 10[3] | 1 | 2 | 1[1] | 2[2] | 0 | 6 |
| 1 and 2 . . . | 14 | 5 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 2[1] | 0 | 0 | 0 | 0 |
| 2 and 3 . . . | 49 | 22 | 7 | 5 | 2 | 0 | 0 | 4[1] | 1 | 3 | 2[1] | 1[1] | 2 | 0 |
| 1, 2 and 3 . . | 12 | 4 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 2 | 0 | 3[1] | 0 | 0 |
| Total . . | 234 | 111 | 34 | 15 | 4 | 5 | 1 | 22 | 5 | 11 | 5 | 11 | 4 | 6 |

[1] One patient in this group had syphilitic lesions.
[2] Two patients in this group had syphilitic lesions.
[3] Three patients in this group had syphilitic lesions.

## CARDIAC MORTALITY AND *T*-WAVE NEGATIVITY.

*T-wave Negativity in Derivation 1.* Information has been received concerning 117 patients having *T*-wave negativity in derivation 1 of their electrocardiograms. Seventy-eight (66.6 per cent.) have died from heart disease during a period of four and a half years (Table X). The mortality in every decade is high; the lowest percentage (45.8) occurred between the ages of forty-one and fifty. Thirty-three patients are alive and 10 of these report their conditions worse, 15 are improved and 8 are unchanged. None of the patients was without cardiac complaints.

TABLE X.—CARDIAC MORTALITY. T-WAVE NEGATIVITY IN DERIVATION 1.

| Decade. | Total. | Patients heard from. | Males. | Females. | Cardiac deaths. | Percentage. | Living. | Worse. | Improved. | Unchanged. | No cardiac complaints. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 to 20 . . . | 2 | 2 | 2 | 0 | 1 | 50.0 | 1 | 0 | 1 | 0 | 0 |
| 21 to 30 . . . | 5 | 5 | 3 | 2 | 3 | 60.0 | 2 | 0 | 0 | 2 | 0 |
| 31 to 40 . . . | 7 | 6 | 6 | 0 | 4 | 66.6 | 2 | 1 | 1 | 0 | 0 |
| 41 to 50 . . . | 28 | 24 | 13 | 11 | 11 | 45.8 | 11 | 2 | 6 | 3 | 0 |
| 51 to 60 . . . | 40 | 32 | 22 | 10 | 21 | 65.6 | 9 | 2 | 5 | 2 | 0 |
| 61 to 70 . . . | 54 | 44 | 33 | 11 | 35 | 79.5 | 8 | 5 | 2 | 1 | 0 |
| 71 to 80 . . . | 4 | 4 | 4 | 0 | 3 | 75.0 | 0 | 0 | 0 | 0 | 0 |
| Total . . . | 140 | 117 | 83 | 34 | 78 | 66.6 | 33 | 10 | 15 | 8 | 0 |

The high cardiac mortality in this group is in accord with the hypothetic and clinical significance, previously emphasized, which attends this *T*-wave negativity. To prevent misunderstanding it may be stated that the negative *T* wave *per se* is only the manifestation of serious underlying myocardial disorder. Changes in cardiac function affecting contraction preponderance resulting from organic or functional myocardial fatigue alter electropotential, which produces *T*-wave negativity.

*T-wave Negativity in Derivation 3.* Information has been received concerning 487 patients having *T*-wave negativity in derivation 3 of their electrocardiograms. Forty-six (9.4 per cent.) have died from heart disease during a period of four and a half years. The data are summarized in Table XI. This relatively low cardiac mortality is sharply contrasted with the mortality of the foregoing group. It is in agreement, however, with the hypothetic and clinical significance accorded *T*-wave negativity in derivation 3.

TABLE XI.—CARDIAC MORTALITY. T-WAVE NEGATIVITY IN DERIVATION 3.

| Decade. | Total. | Patients heard from. | Males. | Females. | Cardiac deaths. | Percentage. | Living. | Worse. | Improved. | Unchanged. | No cardiac complaints. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 to 10 . . . | 10 | 8 | 3 | 5 | 2 | 25.0 | 5 | 0 | 3 | 2 | 3 |
| 11 to 20 . . . | 62 | 42 | 9 | 33 | 2 | 4.7 | 40 | 7 | 20 | 13 | 17 |
| 21 to 30 . . . | 190 | 139 | 22 | 117 | 5 | 3.5 | 127 | 30 | 53 | 44 | 37 |
| 31 to 40 . . . | 161 | 113 | 27 | 86 | 9 | 7.9 | 99 | 23 | 33 | 43 | 25 |
| 41 to 50 . . . | 138 | 89 | 24 | 65 | 9 | 10.1 | 78 | 18 | 30 | 30 | 20 |
| 51 to 60 . . . | 83 | 68 | 37 | 31 | 13 | 19.1 | 53 | 13 | 18 | 22 | 3 |
| 61 to 70 . . . | 39 | 24 | 15 | 9 | 5 | 20.8 | 16 | 6 | 3 | 7 | 1 |
| 71 to 80 . . . | 5 | 4 | 3 | 1 | 1 | 25.0 | 2 | 0 | 1 | 1 | 0 |
| Total . . . | 688 | 487 | 140 | 347 | 46 | 9.4 | 420 | 97 | 161 | 162 | 106 |

TABLE XII.—CARDIAC MORTALITY. T-WAVE NEGATIVITY IN COMBINED DERIVATIONS 1 AND 2

| Decade. | Total. | Patients heard from. | Males. | Females. | Cardiac deaths. | Percentage. | Living. | Worse. | Improved. | Unchanged. | No cardiac complaints. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 to 30 . . . | 7 | 5 | 5 | 0 | 4 | 80.0 | 1 | 0 | 0 | 1 | 0 |
| 31 to 40 . . . | 5 | 3 | 3 | 0 | 3 | 100.0 | 0 | 0 | 0 | 0 | 0 |
| 41 to 50 . . . | 13 | 11 | 9 | 2 | 7 | 63.6 | 3 | 0 | 2 | 1 | 1 |
| 51 to 60 . . . | 20 | 19 | 13 | 6 | 12 | 63.1 | 7 | 1 | 5 | 1 | 0 |
| 61 to 70 . . . | 15 | 12 | 8 | 4 | 7 | 58.3 | 5 | 0 | 5 | 0 | 0 |
| 71 to 80 . . . | 2 | 2 | 1 | 1 | 2 | 100.0 | 0 | 0 | 0 | 0 | 0 |
| Total . . . | 62 | 52 | 39 | 13 | 35 | 67.3 | 16 | 1 | 12 | 3 | 1 |

The potential distribution producing this negativity is but a slight departure from normal. Four hundred and twenty patients are alive, 97 report their conditions worse, 161 are improved and 162 are unchanged. One hundred six patients report no cardiac complaints.

*T-wave Negativity in Combined Derivations 1 and 2.* Of the 52 patients having *T*-wave negativity in combined derivations 1 and 2 concerning whom we have heard, 35 (67.3 per cent.) have died from heart disease during four and a half years. This mortality is greater than was anticipated in that the potential distribution resulting in this *T*-wave negativity was not the greatest departure from normal. In Fig. 4, in which the potential distribution is represented, the right upper zone becomes electropositive to the left instead of electronegative as in the normal, but this is a lesser departure than iso-electric. The fact that the group is relatively small may be a factor in obtaining a high cardiac mortality. Sixteen patients are alive, 1 reports his condition worse, 12 are improved and 3 are unchanged. Only 1 patient reports no cardiac complaint.

*T-wave Negativity in Combined Derivations 2 and 3.* We have learned of the condition of 135 patients having *T*-wave negativity in combined derivations 2 and 3. Thirty-five (25.9 per cent.) have died from heart disease during a period of four and a half years (Table XIII). In contradistinction to the foregoing group the mortality was lower than expected from a hypothetic consideration of potential distribution and associated heart disease. A possible explanation for this discrepancy rests in the fact that 23.3 per cent. of the patients were examined during the last year of the series, and the time element, therefore, is too short to embrace a true mortality average. Eighty-eight patients are alive, 25 report their conditions worse, 37 are improved and 26 are unchanged. Sixteen patients report no cardiac complaints; 7 of these had had thyroidectomies for hyperthyroidism and were cured.

TABLE XIII.—CARDIAC MORTALITY. T-WAVE NEGATIVITY IN COMBINED DERIVATIONS 2 AND 3.

| Decade. | Total. | Patients heard from. | Males. | Females. | Cardiac deaths. | Percentage. | Living. | Worse. | Improved. | Unchanged. | No cardiac complaints. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 to 20 . . . | 12 | 9 | 0 | 9 | 0 | 0 | 9 | 2 | 4 | 3 | 2 |
| 21 to 30 . . . | 45 | 34 | 11 | 23 | 9 | 26.4 | 22 | 7 | 10 | 5 | 6 |
| 31 to 40 . . . | 39 | 32 | 9 | 23 | 5 | 15.6 | 24 | 7 | 9 | 8 | 7 |
| 41 to 50 . . . | 34 | 27 | 16 | 11 | 8 | 29.6 | 17 | 4 | 7 | 6 | 1 |
| 51 to 60 . . . | 28 | 20 | 15 | 5 | 6 | 30.0 | 12 | 2 | 7 | 3 | 0 |
| 61 to 70 . . . | 12 | 12 | 9 | 3 | 6 | 50.0 | 4 | 3 | 0 | 1 | 0 |
| 71 to 80 . . . | 1 | 1 | 1 | 0 | 1 | 100.0 | 0 | 0 | 0 | 0 | 0 |
| Total . . . | 171 | 135 | 61 | 74 | 35 | 25.9 | 88 | 25 | 37 | 26 | 16 |

*T-wave Negativity in Combined Derivations 1, 2 and 3.* Patients having *T*-wave negativity in all derivations comprised a relatively small group. Nineteen of the 38 (50 per cent.) on whom we have had reports have died from heart disease during four and a half years (Table XIV). This mortality agrees fairly well with hypothetic considerations, of potential distribution and associated grave heart disease (Fig. 6). Fifteen patients are alive, 5 report their conditions worse, 8 are improved and 2 are unchanged. No patient was without cardiac complaint.

TABLE XIV.—CARDIAC MORTALITY. T-WAVE NEGATIVITY IN COMBINED DERIVATIONS 1, 2 AND 3.

| Decade. | Total. | Patients heard from. | Males. | Females. | Cardiac deaths. | Percentage. | Living. | Worse. | Improved. | Unchanged. | No cardiac complaints. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 to 20 . . . | 1 | 1 | 0 | 1 | 1 | 100.0 | 0 | 0 | 0 | 0 | 0 |
| 21 to 30 . . . | 4 | 2 | 2 | 0 | 1 | 50.0 | 1 | 0 | 1 | 0 | 0 |
| 31 to 40 . . . | 7 | 5 | 3 | 2 | 2 | 40.0 | 2 | 0 | 1 | 1 | 0 |
| 41 to 50 . . . | 9 | 9 | 6 | 3 | 1 | 11.1 | 6 | 0 | 5 | 1 | 0 |
| 51 to 60 . . . | 12 | 10 | 10 | 0 | 9 | 90.0 | 1 | 1 | 0 | 0 | 0 |
| 61 to 70 . . . | 12 | 11 | 8 | 3 | 5 | 45.5 | 5 | 4 | 1 | 0 | 0 |
| Total . . . | 45 | 38 | 29 | 9 | 19 | 50.0 | 15 | 5 | 8 | 2 | 0 |

In the complete series of *T*-wave negativity, regardless of derivation grouping, information has been received concerning 829 patients. Two hundred and thirteen (25.6 per cent.) have died from heart disease (Table XV).

TABLE XV.—CARDIAC MORTALITY IN COMPLETE SERIES.

| Derivation. | Total. | Patients heard from. | Males. | Females. | Cardiac deaths. | Percentage. | Living. | Worse. | Improved. | Unchanged. | No cardiac complaints. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 . . . . . . | 140 | 117 | 83 | 34 | 78 | 66.6 | 33 | 10 | 15 | 8 | 0 |
| 2 . . . . . . | 688 | 487 | 140 | 347 | 46 | 9.4 | 420 | 97 | 161 | 162 | 106 |
| 1 and 2 . . . | 62 | 52 | 39 | 13 | 35 | 67.3 | 16 | 1 | 12 | 3 | 1 |
| 2 and 3 . . . | 171 | 135 | 61 | 74 | 35 | 25.9 | 88 | 25 | 37 | 26 | 16 |
| 1, 2 and 3 . . | 45 | 38 | 29 | 9 | 19 | 50.0 | 15 | 5 | 8 | 2 | 0 |
| Total . . . | 1106 | 829 | 352 | 477 | 213 | 25.6 | 572 | 138 | 233 | 201 | 123 |

A group of cases was compiled including those cases in which there was *T*-wave negativity without other electrocardiographic abnormalities except ventricular preponderance. This was done with the idea of excluding disorders of cardiac action known in themselves materially to influence cardiac mortality, especially auricular fibrillation and flutter, ventricular tachycardia, delayed auriculoventricular conduction, complete auriculoventricular dissociation and arborization block. Of the 559 patients in this group of whose condition we have learned, 92 (16.4 per cent.) have died from heart disease (Table XVI). The cardiac mortality in this group is 9.2 per cent. less than that of the complete series.

TABLE XVI.—CARDIAC MORTALITY. T-WAVE NEGATIVITY WITHOUT OTHER ELECTROCARDIOGRAPHIC ABNORMALITIES.

| Derivation. | Total. | Patients heard from. | Males. | Females. | Cardiac deaths. | Percentage. | Living. | Worse. | Improved. | Unchanged. | No cardiac complaints. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 . . . . . . | 41 | 32 | 21 | 11 | 17 | 53.1 | 13 | 4 | 7 | 2 | 0 |
| 3 . . . . . . | 550 | 394 | 86 | 308 | 33 | 8.3 | 349 | 76 | 132 | 141 | 83 |
| 1 and 2 . . . | 32 | 29 | 23 | 6 | 17 | 58.6 | 12 | 1 | 8 | 3 | 1 |
| 2 and 3 . . . | 112 | 86 | 33 | 53 | 17 | 19.7 | 61 | 18 | 28 | 15 | 14 |
| 1, 2 and 3 . . | 21 | 18 | 15 | 3 | 8 | 44.4 | 7 | 2 | 4 | 1 | 0 |
| Total . . . | 756 | 559 | 178 | 381 | 92 | 16.4 | 442 | 101 | 179 | 162 | 98 |

## CONCLUSIONS.

1. The ventricular complexes of the electrocardiogram are the expressions of two distinct processes, impulse conduction and muscle contraction.
2. The *T* wave is the expression of preponderance of contraction on one side of the line of equipotential (Eyster and Meek).
3. *T*-wave negativity results from alteration in potential distribution from changes in contraction preponderance. Changes in contraction preponderance may result from changes in blood volume and from organic or functional myocardial fatigue.
4. The occurrence of *T*-wave negativity in certain isolated and combined derivations of the electrocardiogram bears a fairly definite relationship to degrees of cardiac damage.
5. The significance of *T*-wave negativity in this series as evidence of heart disease in order of gravity is in (1) combined derivations 1 and 2; (2) derivation 1; (3) combined derivations 1, 2 and 3; (4) combined derivations 2 and 3; and (5) derivation 3.
6. *T*-wave negativity in derivation 2 and in combined derivations 1 and 3 has not been observed in the Mayo Clinic and according to the hypothesis cannot exist. Such negativity would indicate a diffuse iso-electric state of the heart which would mean cardiac standstill.

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# ILEAL REGURGITATION, NERVES AND DIET IN THE CHRONIC INTESTINAL INVALID.*

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I. Introduction. Since 1566[1] it has been known there is a structure called the ileocecal valve, and it has been known since 1570[2] that the valvular function of this structure is to prevent the regurgitation of feces into the small intestine. Furthermore, it has been known for ninety-eight years[3] that the active muscular sphincteric function of the mechanism at the distal end of the ileum is to moderate the flow of the contents of the small intestine into the colon.

Actual incompetence of the ileocecal valve was first produced experimentally in 1586.[4] This condition has been recognized as a clinical entity for twenty-three years,[5] and its existence was demonstrated in the human by the bismuth-roentgen method at least eighteen years ago.[6] Yet Cole,[6] writing six years ago, was obliged to bemoan the fact that he was unable to arouse any interest in this subject, even on asking if symptoms might be expected, should a patient be fed colonic contents. Cole, Case and other authorities in roentgen work have recognized a correlation in the degree of ileal regurgitation and the severity of the symptoms complained of by

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